REMARKS

Restriction R quirement:

Applicants hereby affirm the election to prosecute the invention of Group I, Claims 1 - 17, 20 - 29, 32 - 38, and 41 - 48.

Novelty Rejections:

Claims 1 - 4, 8 - 13, 16, 17, 20 - 29, 32, and 41 - 44 stand rejected as being anticipated by a paper authored by Kondo, et al., entitled *Three-Dimensional Microdrilling of Glass by Multiphoton Process and Chemical Etching*. Kondo, et al. describe a multiphoton process in which femtosecond pulses are used to write waveguides inside optical substrates. Although Kondo, et al. do not provide any explicit direction for manipulating a transverse dimension of the waveguides, the Examiner notes that a "Y" coupler written by Kondo, et al. has an enlarged diameter at a juncture of two branches. The Examiner also holds that certain claim language requiring first and second tracks to be substantially parallel is read upon by the "Y" coupler since the specification does not distinguish the two.

The first three of the four independent claims 1, 20, 32, and 41 have been amended to more precisely distinguish the intended manipulation of waveguide diameter from the coincidental features of a "Y" coupler. Independent Claim 1, for example, has been amended in several respects. Claim 1 now specifies that the waveguide produced by the relative motion of the spot focus is a single waveguide having a longitudinal dimension along a first track of relative motion. The further relative motions are now required to enlarge a transverse dimension of the single waveguide within a boundary surrounded by the substrate. An additional step is appended to Claim 1 that relates the further relative motion to the first track of relative motion so that the enlarged transverse dimension remains within the boundary of the single waveguide along the longitudinal dimension of the single waveguide.

The "Y" coupler of Kondo et al. is not a single waveguide and whatever motion Kondo et al. might have used for forming the branches of a "Y" coupler in the enlarged transverse dimension of the "Y" coupler does not remain within the boundary of the single waveguide along the longitudinal dimension of the single waveguide. By its very nature, the "Y" coupler splits into two separate waveguides each having its own boundary.

Dependent claims 8-13 require additional relationships among the recited relative motions that are not found in Kondo et al. Claim 8, for example, requires the relative motion adjacent to the first track that enlarges the transverse dimension of the diameter to be imparted simultaneously with the relative motion along the first track that enlarges the longitudinal dimension of the waveguide. Claim 9 specifies that the further relative motion has a velocity component normal to the direction of motion along the first track. Kondo et al. traces the "Y" coupler by simple translation. No suggestions are made for additional simultaneous motions that would enlarge the transverse dimension of the waveguide. Claim 13 requires the simultaneous relative motion to include an angular velocity. Nothing but translation is considered by Kondo et al.

Independent Claim 20 has been amended to include a step of further relating the specified relative translations so that the juxtaposed first and second sections of the waveguide remain continuous along a common length of these sections in the direction of the relative translation. The two sections of Kondo et al.'s "Y" coupler do not remain contiguous along their common length. Again, by their very nature, they must not.

Dependent claim 22 requires the further relative rotation enlarging the transverse dimension of the waveguide to trace more than two sections of the waveguide. The "Y" coupler of Kondo et al. has but two branches. Dependent claims 27 and 28 specify arrangements of the additional sections (more than two) such as vertices of a polygon. The "Y" coupler of Kondo et al. has only two branches in the form of a "Y". Dependent Claim 29 specifies that the refractive

index of the center section traced in the substrate is different than the refractive index of the peripheral sections traced in the substrate. Nothing in Kondo et al. equates with writing central and peripheral traces with different indices of refraction.

Independent Claim 32 is distinguished by a further limitation requiring the recited second component of the relative motion to be related to the first component of the relative motion, so that the enlarged transversed dimension of the waveguide is undivided and coextensive with the enlarged longitudinal dimension of the waveguide. Any enlarged portion of Kondo et al.'s "Y" coupler is limited to an intersection of two waveguides and the enlarged transversed dimension apparent at an intersection is not undivided and coextensive with the enlarged longitudinal dimension of the "Y" coupler. The "Y" coupler divides into separate branches following the intersection.

Independent Claim 41 is distinguished as filed from any methods found in Kondo et al. by requiring the irradiation of a plurality of adjacent spots within a substrate with a plurality of pulsed laser beams and by requiring relative translation of the substrate with respect to the plurality of adjacent spots of irridation for tracing a waveguide. Kondo et al. give no indication of how a plurality of lasers might be used in conjunction with relative motion for tracing a waveguide in the substrate. Kondo et al. Disclose use of a single laser illuminating a single spot and relative motion for tracing single waveguides and "Y" couplers.

The remaining dependent claims 42-44 further specify characteristics of the pulsed laser beams, the separate spots illuminated by the beams. Kondo et al. use a single beam that has none of these characteristics.

Claims 1 - 3, 8, 9, 13, 16, 17, 20, 21, 32, and 41 - 44 stand rejected as being anticipated by a paper of Hirao et al. entitled *Writing Waveguides and Gratings in Silica and Related Materials by a Femtosecond Laser.* The Examiner draws from Figure 1 the assumption that two orthogonally oriented waveguides

written into an optical substrate (sample) intersect and takes notice that the intersection produces a waveguide with a wider transverse dimension. In this regard, Hirao et al. only say that glass samples can be translated either parallel or perpendicular to the incident laser beam for creating damage lines inside the glasses.

The noted orthogonal intersection of linear waveguides is more remote from the claimed invention than the "Y" branched intersection of Kondo et al. because the intersecting waveguides share no common longitudinal or transverse dimensions. The same limitations that distinguish Kondo et al. also distinguish the claimed invention over Hirao et al., whose closest approach to the invention is an illustration of two orthogonal waveguides that has even less to do with modifications to the transverse dimensions of waveguides. Moreover, Hirao et al. describe an entirely different method for modifying waveguide diameters. As shown in Figure 4, Hirao, et al. demonstrate the effects of varying average laser power on waveguide diameters. Waveguide diameters are shown to increase with the amount of power applied. Nothing is said about using any combination of relative motions between focus spots and substrates to enlarge waveguide diameters. Nothing is said about using multiple lasers in combination with such relative motion for filling transverse dimensions of waveguides. Any waveguide widening limited to intersections is now clearly distinguished by the amendments made to the claims.

Claims 1 - 4, 8 - 13, 16, 17, 20 - 29, 32, and 41 - 44 stand rejected as being anticipated by authors Homoelle et al. in a paper entitled *Infrared Photosensitiveity in Silica Glasses Exposed to Femtosecond Laser Pulses*. Similar to the preceding references, Homoelle et al. discuss a multiphoton process for writing waveguides in glass. One of the inventors of the subject application is listed among the authors of this paper. Again, the only connection with the objectives of the subject invention for enlarging transverse dimensions of waveguides is the assumed local enlargement at the instant junction of a "Y" coupler. Nothing more of relevance is disclosed here than the notice already

taken concerning "Y" couplers of Kondo et al., and the claims are now clearly distinguished over the known methods of producing "Y" couplers.

Claims 1 - 3, 8, 9, 13, 16, 17, 20, 21, 32, and 41 - 44 stand rejected as being anticipated by a paper of Davis et al. entitled *Writing Waveguides in Glass with a Femtosecond Laser.* The same drawing figure as the figure cited in the Hirao et al. paper appears here and is presumed to be of the same relevance. The claims have already been amended to distinguish the claimed method for increasing the transverse dimension of a waveguide along its length from the intersection of two waveguides, and nothing more is said in Davis et al. to suggest the particular combinations of motions set forth in the claims for accomplishing the objectives of the subject invention. In addition, Davis does not propose to fill the transverse area of waveguides with the focus spots of multiple beams.

Claims 1 - 3, 8, 9, 13, 16, 17, 20, 21, 32, and 41 - 44 stand rejected as being anticipated by a presentation of Hirao et al. entitled *Internal Modification of Glass Materials with a Femtosecond Laser.* Again, beyond a multiphoton process shared by the subject invention, the Hirao, et al. connection to the manipulation of waveguide transverse dimensions is limited to the illustration of crossing waveguides. The assumption by the Examiner has been that such crossing waveguides also intersect. While possible, it is not clear from the drawing and its lack of explanation in that regard whether they intersect or not. Applicants have taught that attempting to write through an area that has been previously written has undesirable focusing effects on the writing beam that can disrupt the further writing of waveguides. Thus, if it were Hirao et al.'s intention write one waveguide through another, focusing problems would be expected and results less than certain. There is no teaching as to how combinations of relative motions should be used to enlarging waveguides along their length.

Claims 1 - 4, 8 - 13, 16, 17, 20 - 29, 32, and 41 - 44 stand rejected as being anticipated by International Publication WO 01/098999 of Borrelli et al.

(one of the named inventors of the instant application). Here, Borrelli discloses the use of the multiphoton process for making three dimensional light guiding structures within the interiors of glass bodies. Among the written structures are "Y" couples and star couplers. Similar "Y" couplers have appeared in the references already distinguished. The Star coupler includes a number of separate but parallel waveguides. However, unlike the "Y" coupler, the waveguides of the star coupler are not joined together at any point. Each retains its own transverse boundary surrounded by unmodified substrate and separate from the other waveguides. The Examiner also notes with respect to Borrelli et al. the use of hourglass foci shapes, which is the expected cross-sectional shape of a focused beam. According to this earlier writing of Borrelli et al., the focus can be moved parallel to the direction of beam propagation or perpendicular to the direction of beam propagation. However, similar to the other references discussed above, there is no mention of the required combination of relative motions set forth for the present invention to enlarge a transverse dimension of a waveguide along its length. In addition, no mention is found for translating a substrate with respect to a plurality of focused beams for achieving this effect.

Obviousness Rejections

Claims 1 - 13, 16, 17, 20 - 29, 32, 36 - 38, 41 - 44, and 46 - 48 are rejected over any one of the preceding references to Borrelli, et al., Homoelle et al., and Kondo et al. or over US Patent 6,573,026 to Aiken et al. (which claims priority in common with the Borrelli et al. International patent application) in view of a paper of Itoh et al. entitled *Fabrication of Small Bragg Reflectors in Glass with Refractive Index Change Induced by Ultrashort Laser Pulses*, and in view of US Patent 5,022,957 to Copley et al.

The Aiken patent is specifically cited for describing a multiphoton process for forming star couplers of the type shown in Figures 11a through 11d, which correspond to the star coupler disclosed in the previously distinguished International application of Borrelli et al. Itoh et al. is said to teach the formation

of parallel rectangular stripes where dimensions differ significantly. US Patent 5,022,957 to Copley et al. is added to the combination for disclosing laser machining techniques with CO_2 lasers operating on the surface of articles in conjunction with an etching solution.

Of all of the references supplied by the Examiner in constructing this rejection, only one --the paper of Hirao et al. entitled *Writing Waveguides and Gratings in Silica and Related Materials by a Femtosecond Laser*-- actually deals with the problem of enlarging waveguide diameters, and in this paper, Hirao et al. suggest doing so by varying the average laser power. None of the references suggest using the claimed combination of relative motions or multiple beam arrangements for the purpose of enlarging the transverse dimension of waveguides along their length. While the lack of any intention to perform the steps required by the claimed invention for the purposes of the invention is of diminished significance to the issue of novelty, this lack of purpose or direction is relevant to the consideration of obviousness where the references applied require modifications beyond their intended purposes.

All of the references cited for novelty, as well as the assignee's own Aiken et al. patent describe the background in which the invention was made. The references show that multiphoton processes involving laser pulses within the femtosecond range had been focused within optical substrates for writing waveguides and certain other optical structures, including coupling devices. Little, however, was known about controlling the diameter or transverse shape of the waveguides. What was known is that waveguide diameters, at least in some materials, can be enlarged by additional laser power.

The Itoh et al. paper is cited in combination with the other references for teaching the formation of parallel rectangular stripes where the dimensions differ significantly. The paper describes efforts to fabricate Bragg gratings using multiphoton processing. A succession of planar traces were made by exploiting special self-focusing effects associated with multiphoton processing. The planar

traces were necessarily separated from one another to avoid any index changes in the spaces between the traces that would undermine the effectiveness of the intended Bragg grating. Nothing in Itoh et al. suggests the use of the particular relative motions set forth for the present invention by claims 1 - 13, 16, 17, 20 - 29, 32, and 36 – 38 or the combination of multiple laser sources with relative motion set forth by claims 41 - 44 and 46 - 48. Itoh et al. does contribute information about how to form gratings in waveguides, but absent some direction, this information is not sufficient to lead one of skill to make the further modifications required to enlarge the transverse dimensions of waveguides along their lengths. Itoh et al.'s procedures do not produce this result and no such result can be expected by combining these procedures.

The disclosure of Copley et al. is directed to an entirely different form of laser machining in which a laser power is applied to the surfaces of substrates in combination with chemicals for etching. Neither the chemicals nor the pulse energies contemplated by Copley et al. are effective for writing inside of substrates. The purpose of the Copley et al. invention is to improve the strength of articles formed on the surfaces of silicon-based ceramic materials having laser machined surfaces. This is not a teaching that would direct others to modify their multiphoton processing systems to carry out heretofore unknown procedural changes to accomplish a goal that is not set by Copley et al. for machining the surfaces of substrates.

Copley et al.'s suggestions for laser machining include the formation of parallel groves that can be cut at progressive depths through the surface of a substrate. The material of an underlying layer is not removed until the underlying material is exposed by the removal of an overlying layer. However, for writing inside a substrate, the surface materials cannot be removed. Techniques that have been long developed for writing and shaping the surfaces of articles do not find exact counterparts to the multiphoton laser processes developed for writing inside substrates, where the writing beam must be conveyed through the substrate without damaging the substrate until a certain threshold conditions are

reached. The pulse energies contemplated for the present invention at wavelengths beyond the absorption edge of the substrate and at pulsed durations less than 150 femtoseconds do not produce comparable results on the surfaces of solids, and the pulse energies employed by Copley et al. on the surfaces of solids do not have the same effect within the solid interiors.

Copley et al. cannot be looked to supply either the missing direction or the missing information about how to enlarge transverse dimension of waveguides as set forth in the claimed invention for several reasons. First, Copley et al. do not teach how to form waveguides at all. The removal of material from a surface does not form a waveguide. Second, whatever procedures Copley et al. might use for the removal of surface layers are not immediately applicable to the formation of waveguides inside of substrates.

Claims 1 - 17, 20 - 29, 32 - 38, and 41 - 48 stand as being obvious over the same combination of base art in view of a paper of Miura et al. entitled *Preparation and Optical Properties of Fluoride Waveguides Induced by Laser Pulses* and the Itoh et al. paper. Miura et al. is cited for teaching that the use of serial laser pulses over the same area does not significantly increase the size of features. This is a conclusion that was also reached in other of the papers. It eliminates one possibility for how to enlarge waveguide diameters but does not contain any positive suggestions for how waveguide diameters might actually be increased.

US Patent 6,407,363 to Dunsky et al. is appended to the combination for teaching the use of "a spiral path to form a circular pattern by nibbling the edge to achieve the final desired shape." The Dunsky et al. patent like the Copley et al. patent refers to the machining of surfaces with laser beams operating in an energy regime appropriate for removing surface materials, and such teachings are not immediately applicable to the different energy regimes required for writing inside optical materials. The multiphoton processes relevant to the claimed invention formed by waveguides making small changes the refractive index of

interior materials. The techniques taught by Dunsky et al. and Copley et al. remove material from the surfaces of substrates. Neither of these techniques results in the formation of a waveguide.

None of the cited references concerned with multiphoton processes using femtosecond pulses for writing waveguides inside of substrates has made any suggestions even close to those of the claimed invention for enlarging the transverse dimensions of waveguides along their lengths. The two references cited beyond the art of multiphoton processing with femtosecond pulses, teach machining techniques applied to the surfaces of substrates, which are not applicable to writing inside substrates. In addition, the surface material removal techniques of the references do not result in the formation of waveguides.

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In view of the above amendments and remarks, all of the elected claims 1 - 17, 20 – 29, 32 – 38, and 41 – 48 are now believed to be in condition for allowance. Reconsideration and allowance of these claims is respectfully requested. For any questions concerning this Amendment please contact the undersigned at the telephone number listed below.

Respectfully submitted,

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